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Phys 131L
Fall 2016

Laboratory 6: Newton's Second Law for a Single Object

Newton's laws provide a framework for determining the acceleration of any object. The framework requires that all the forces, $\vec{F}_1, \vec{F}_2, \vec{F}_3, \ldots$, that act on the object are known. The acceleration, $\vec{a}$, of the object is given indirectly by Newton's second law,

$$\vec{F}_{\text{net}} = m\vec{a}$$

where m is the mass of the object and the net force is given by

$$\vec{F}_{\text{net}} = \sum_i \vec{F}_i = \vec{F}_1 + \vec{F}_2 + \vec{F}_3 + \ldots.$$

In this laboratory you will test this for an object that can slide along an inclined ramp.

Separately you will also test some of the theory regarding friction forces.

1 Cart sliding along a ramp: theory

Consider a cart, of mass m, that slides along a frictionless ramp, whose surface is at an angle θ from the horizontal.

a) Draw a free body diagram for the cart.

b) Use you free body diagram to predict whether the acceleration of the cart will be different when the cart is sliding up the ramp versus down the ramp.

c) Apply Newton's second law to determine an expression for the magnitude of the cart's acceleration, a. This should have the form

$$a = \text{formula possibly involving only } g, \theta \text{ and } m.$$

d) Does your formula predict that the mass of the cart will affect the acceleration?

e) Does your formula predict that the acceleration of the cart as it moves up the slope will be different from that when it moves down the slope?

2 Cart sliding along a ramp: experiment

a) Start DataStudio and connect the motion sensor. Set the sample rate to 25 Hz. Configure DataStudio to display a graph of velocity versus time.

b) Prop the track up so that the motion sensor is at the top of the resulting ramp.

c) Describe how to determine the angle that the track makes with respect to the horizontal by using various measurements of lengths and heights (measuring the angle directly using a protractor will be much less accurate.

106 m

d) Use the technique from part (c) to determine the angle that the track makes with respect to the horizontal.

e) Hold the cart at the bottom of the ramp. Start data acquisition and give the cart a gentle push up the slope. DataStudio should produce a graph of velocity versus time. **Important:** the older versions of the motion sensor do not record position of an object that is closer to the sensor than 50 cm accurately. An example of this is illustrated in Fig. 1. Discard any run in which this or worse happens.

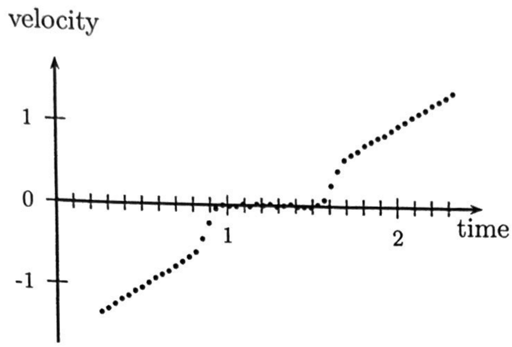

Figure 1: Data recorded when the cart approached too close to the motion sensor. During the time interval from about 0.8 s to 1.6 s, the motion sensor did not record the cart's position correctly.

f) Determine the acceleration of the cart from the graph of velocity versus time.

g) Predict the acceleration using the formula developed in the theory part of this exercise. Determine the percentage difference between the measured and predicted acceleration.

h) Repeat parts (d) to (g) for three other slope angles. Ensure that you save the data from each good run.

i) Display the graph of velocity versus time for the first slope angle and identify the instant at which the cart reaches its highest point on the ramp. Determine the acceleration of the cart as it slides up the ramp. Separately determine the acceleration as it slides down the ramp. Are these the same? If not which is larger?

j) Repeat part (i) using the graphs for all the other slope angles for which you obtained data. You should observe that there is always a discrepancy between the acceleration of the cart as it slides up the ramp compared to that as it slides down. For each slope angle, is the acceleration as the cart ascends always larger than that as it descends or always smaller?

k) Explain why there is a discrepancy in the accelerations for upward versus downward motion. Your explanation must start with a free body diagram of all the forces and must use Newton's Second Law to arrive at a conclusion about the magnitude of the acceleration. What does your analysis predict about the magnitudes of the accelerations? Will the acceleration for upward motion always be larger than or smaller than that for downward motion? How does this compare to what you observed?

3 Friction

a) Restart DataStudio, connect the Force Sensor and set the sample rate to 1000 Hz. Configure DataStudio to display a graph of force versus time.

b) Place the block on the table with the larger felt (or cork) surface down. Connect the block to the force sensor via a loop of string. Place about 1500 g of additional mass on top of the block.

c) Start data acquisition while the force sensor is **not** pulling. The force sensor reads the force exerted by the string and at this point it should read 0.0 N. However it frequently will not. This can be corrected by pushing the tare button on the side of the force sensor. Do this and verify that the sensor now reads 0.0 N. You may have to do this frequently throughout this experiment.

d) Gently pull on the block with the force sensor. The block should initially remain at rest and eventually start moving. Once the block is moving try to keep it moving at a constant speed. You should obtain a plot of force versus time similar to that of Fig. 2. The force sensor is configured to read negative forces

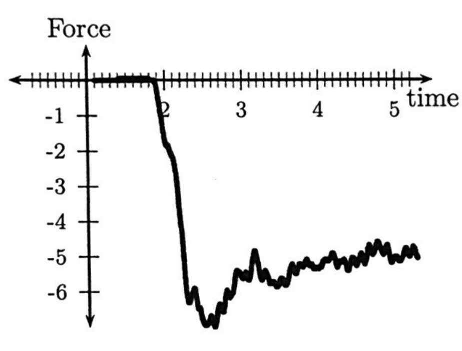

Figure 2: Force versus time for a block that is pulled from rest.

when it is pulled; thus the graph is beneath the horizontal axis. Key features that **must appear** in your graph are: first a large downward spike, second a slight upward rise and, third an approximately horizontal section. In Fig. 2 the downward spike reaches a maximum at about 2.5 s and the slight upward rise occurs between 2.5 s and 3.0 s. Between 3.0 s and 5.0 s the graph is roughly level. There will usually be many smaller erratic and jagged fluctuations. Repeat the experiment until you obtain a graph with the large downward spike followed by the upward rise and approximately level section. Save your data.

e) Use Newton's second law to predict how the force exerted by the string on the block compares to the static friction force while the block is at rest. Use your data to determine the maximum static friction force.

f) Use Newton's second law to predict how the force exerted by the string on the block compares to the kinetic friction force while the block is moving with constant speed. Use your data to determine the kinetic friction force.

g) Repeat parts (d) to (f) at least three times for the same setup, i.e. the same block lying on the same side and carrying the same masses. The results will vary somewhat. Determine an average value for the maximum static friction. Determine an average value for the kinetic friction. Use these to determine the coefficients of static and kinetic friction.

h) Now repeat the entire experiment with smaller felt (or cork) surface down. Do the friction forces depend significantly on the contact area of the block?

i) How does the coefficient of static friction compare (larger, smaller, same) to the coefficient of kinetic friction for these surfaces?

4 Conclusion

a) What does this experiment establish regarding Newton's second law?

b) What does this experiment establish regarding friction forces?

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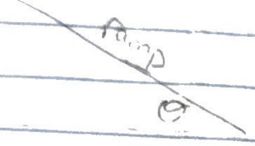
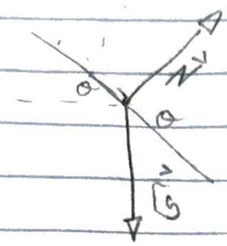
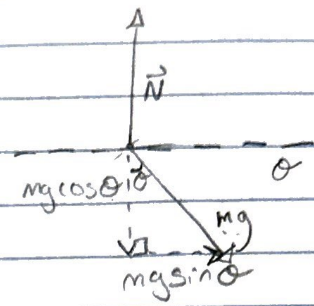
a.







$\Sigma x = ma_x$
$\Sigma y = ma_y$

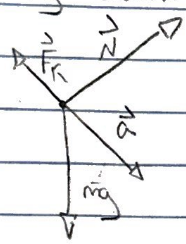
F	x	y
$\vec{N}$	0	N
$\vec{F_G}$	mgsinθ	-mgsinθ

$y = mg\sin\theta$
$x = mg\cos\theta$

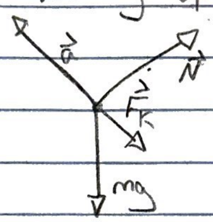
$\vec{N} - mg\cos\theta = ma_y = 0$
$N = mg\cos\theta$ ✓
$\Sigma x = mg\sin\theta = ma_x$
$g\sin\theta = a_x$ ✓

b.)

Moving Down



Moving up



c.)

$\Sigma x = ma_x$

$0 + mg\sin\theta = ma_x$

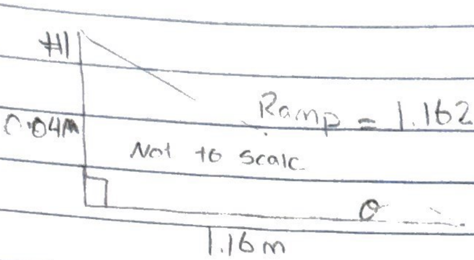
$g\sin\theta = a_x$ ✓

d.) No it does not because the algebra in the previous step cancels out mass when we solve for a_x.

e.) our formula does not predict a different acceleration when it moves up.

2

c. #1



$\sin\theta = \frac{O}{H}$

$\theta = \sin^{-1}\left(\frac{0.04}{1.162\,m}\right)$

$\theta = 1.97°$ ✓

d. $\theta = 3.41°$

f. Graph says slope is 0.291 which means the acceleration is 0.291 m/s^2

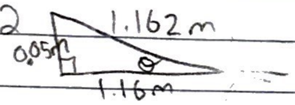
g. $a_x = g\sin\theta$ $\theta = 3.41$ units?

$a_x = 9.8\sin(1.97)$ $g = 9.8$ ok

$a_x = 0.32\ m/s^2$ ✓ Linear fit line $0.28\ m/s^2$ ✓

Missing 4 and 5

H #2



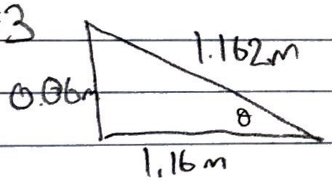
$\sin^{-1}\left(\frac{0.05}{1.162}\right) = \theta$ -2

$\theta = 2.47°$ ✓

$g\sin 2.47$

$9.8\ m/s^2\ \sin 2.47 = 0.42\ m/s^2$ Linear fit line $0.345\ m/s^2$ ✓

#3



Linear fit line $0.459\ m/s^2$

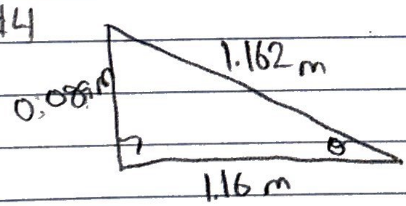
$g = 9.8\ m/s^2$

$\theta = \sin^{-1}\left(\frac{0.06m}{1.16m}\right)$

$\theta = 2.96°$ $g\sin\theta = 9.8\sin 2.96$

$a_x = .51\ m/s^2$ ✓

#4



Linear fit line $0.477\ m/s^2$ ✓

$\theta = \sin^{-1}\left(\frac{.08}{1.162}\right)$ $g\sin\theta = a_x$

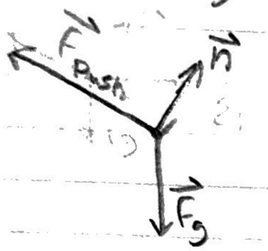
$\theta = 3.94$ $9.8\sin 3.94 = .67$

$a_x = .67\ m/s^2$ ✓

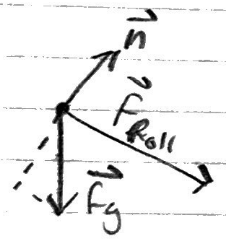
i. The cart reached its highest point at around 3s since its velocity is zero. The acceleration of the cart is not the same going up as it is going down the ramp. The cart going up the ramp has a greater velocity.

j. The cart always has a slightly greater acceleration in every trial we ran.

k. cart going up ramp



cart going down ramp



Due to Newton's 2nd Law the acceleration of the cart descending would be greater. this is due to the fact it is no longer fighting gravity and uses the x component of its fg to have a greater acceleration.

force descending has gravity.

Newton's 2nd law

ascending cart

$$\Sigma F_{net} = \frac{F_{push} - f_{gx}}{m} = a_a$$

descending cart

$$\Sigma f_{net} = \frac{f_{Roll} + f_{gx}}{m} = a_d$$

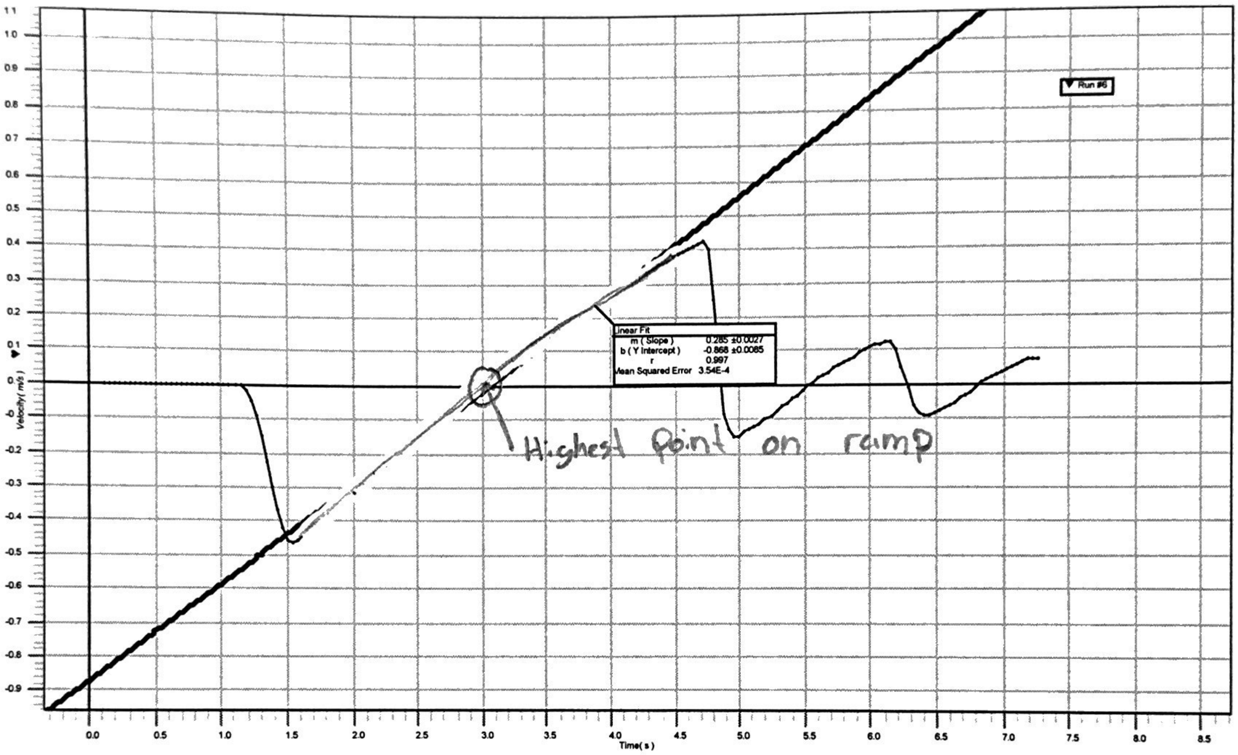
The acceleration will always be greater going down. This is opposite of our results. This could be due to the fact in the early seconds it could be our hand accelerating it.

4. Conclusion

a) This experiment establishes that you can solve for many diffrent variables and also use it as a proff in certain situations.

b) was told to disregard friction.

Graph 1


Run #6
Linear Fit
m (Slope) 0.285 ±0.0027
b (Y Intercept) -0.868 ±0.0085
r 0.997
Mean Squared Error 3.54E-4
Highest Point on ramp
Velocity(m/s)
Time(s)

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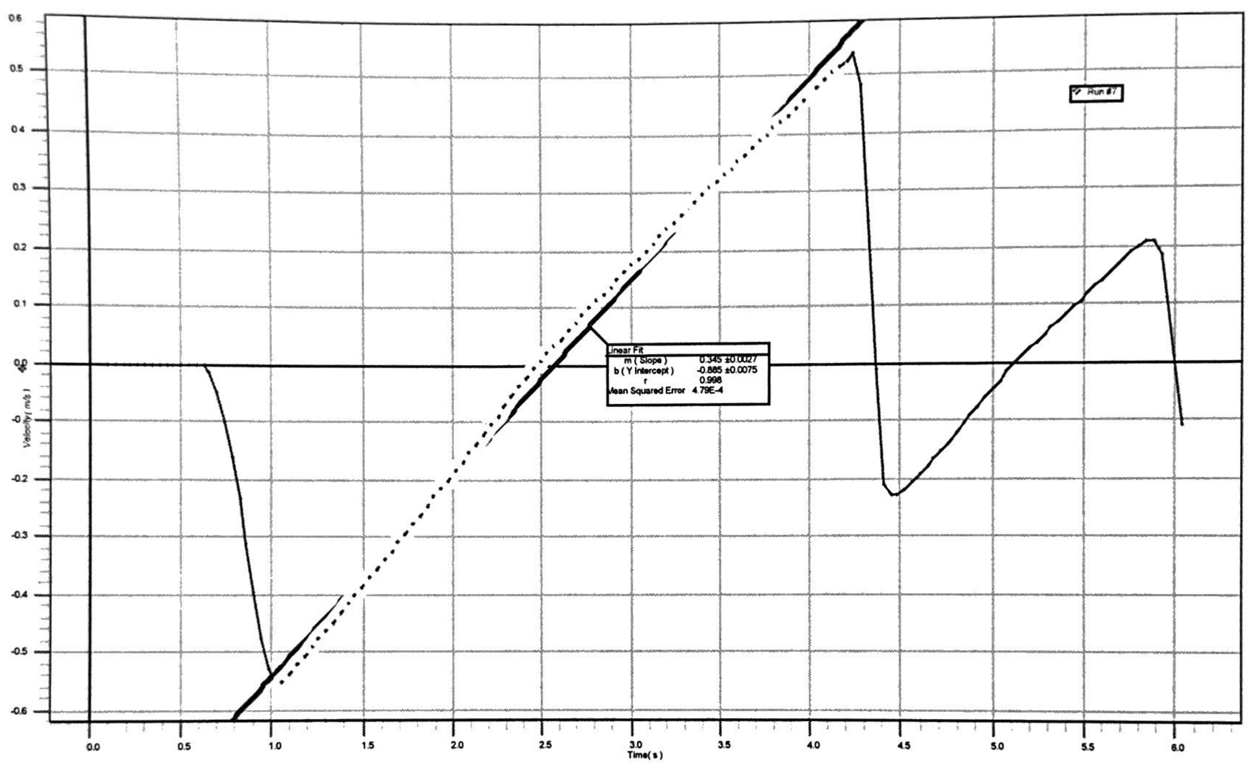
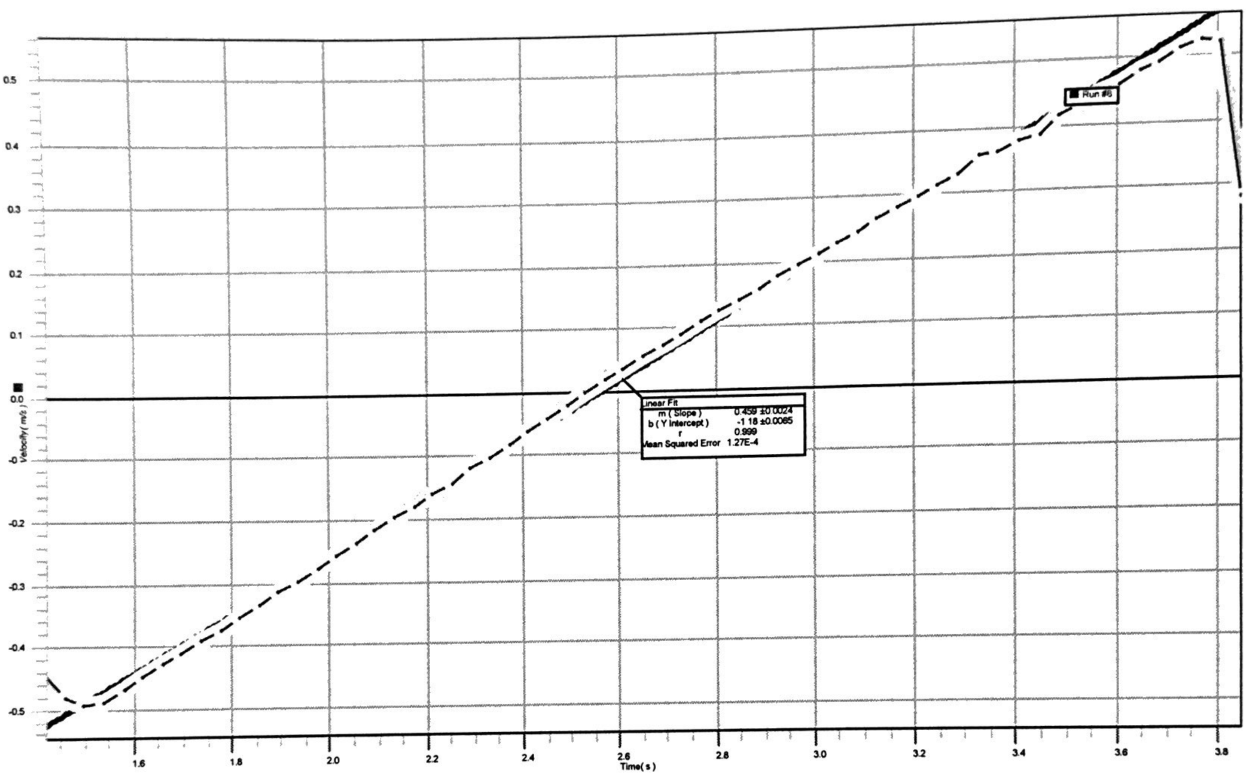
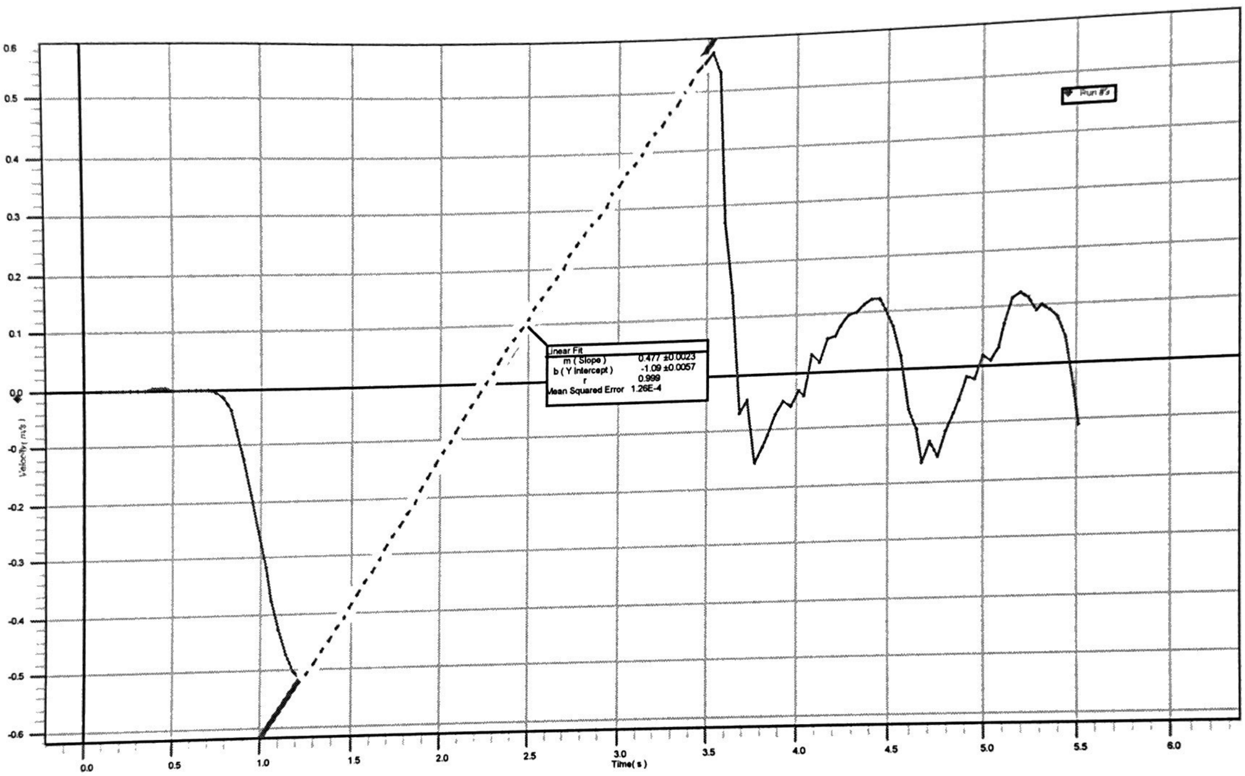
Graph 1



Graph 1


Run #6
Linear Fit
m (Slope) 0.459 ±0.0024
b (Y Intercept) -1 18 ±0.0065
r 0.999
Mean Squared Error 1.27E-4
Time(s)
0.5
0.4
0.3
0.2
0.1
0.0
-0.2
-0.3
-0.4
-0.5
1.6
1.8
2.0
2.2
2.4
2.6
2.8
3.0
3.2
3.4
3.6
3.8

Graph 1


Linear Fit
m (Slope) 0.477 ±0.0023
b (Y Intercept) -1.09 ±0.0057
r 0.999
Mean Squared Error 1.26E-4
Run #'s
Time(s)
0.0
0.5
1.0
1.5
2.0
2.5
3.0
3.5
4.0
4.5
5.0
5.5
6.0
0.6
0.5
0.4
0.3
0.2
0.1
0.0
-0.2
-0.3
-0.4
-0.5
-0.6